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World Leader in Ultra-Clean Power

Co-production of Hydrogen and Electricity (A Developer's Perspective)

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FuelCell Energy, Inc.

Transportation and Stationary Power Integration Workshop

Fuel Cell Seminar 2008

Phoenix, AZ

October 27, 2008

reliable, efficient, ultra-clean

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Presentation Outline

- FuelCell Energy Overview
- Direct Fuel Cell (DFC) Technology Status
- Hydrogen Co-production Technology, Benefits and Status
- Strategic Input for the DOE Workshop

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FCE Overview

- **Leading fuel cell developer for over 30 years**
  - **MCFC, SOFC, PAFC and PEM (up to 2 MW size products)**
  - **Over 230 million kWh of clean power produced world-wide (>60 installations)**
  - **Renewable fuels: over two dozen sites with ADG fuel**
  - **Ultra-clean technology: CARB-2007 certified**

Danbury, CT

- **Highly innovative approach to fuel cell development**
  - **Internal reforming technology (45-50% electrical efficiency)**
  - **Fuel cell-turbine hybrid system (55-65% electrical eff.)**
  - **High temperature polymer membrane: leverage existing experience in composite membranes for other fuel cell systems (PAFC, MCFC, SOFC) for low-cost H_2 separation**
  - **Enabling technologies for hydrogen infrastructure**

    Co-production of renewable H_2 and e^- (60-70% eff. w/o CHP)

    Solid state hydrogen separation and compression

Torrington, CT

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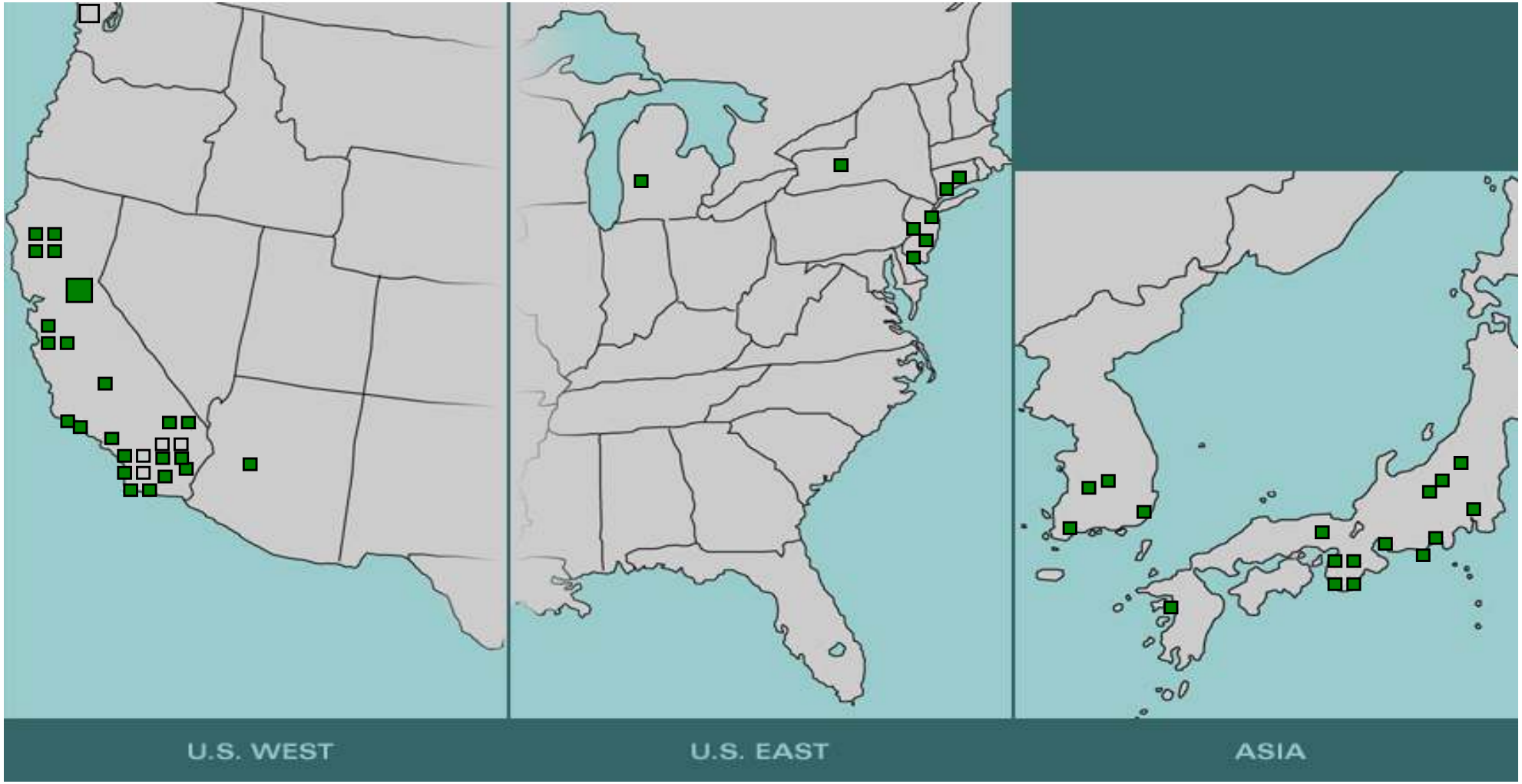
FuelCell Energy Power Plant Locations



- **Over 60 global units, 230 million kWh produced at customer sites**
- **More than 10,000 kg H_2/day being produced at CA alone – mostly from renewable fuels (ADG)**

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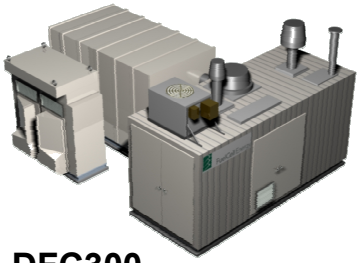
Building Block Approach to Product Line

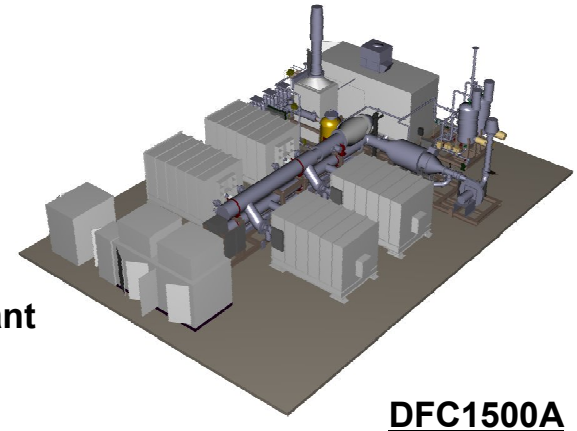
Cell Package and Stack

Single-Stack Module

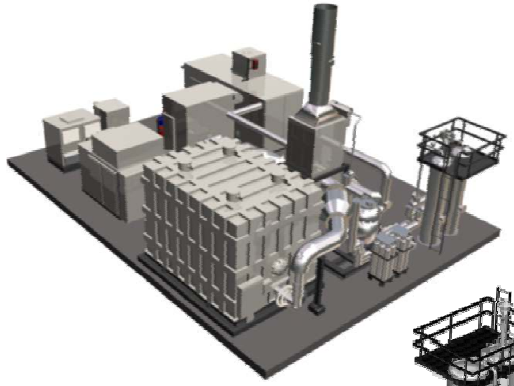
Four-Stack Module



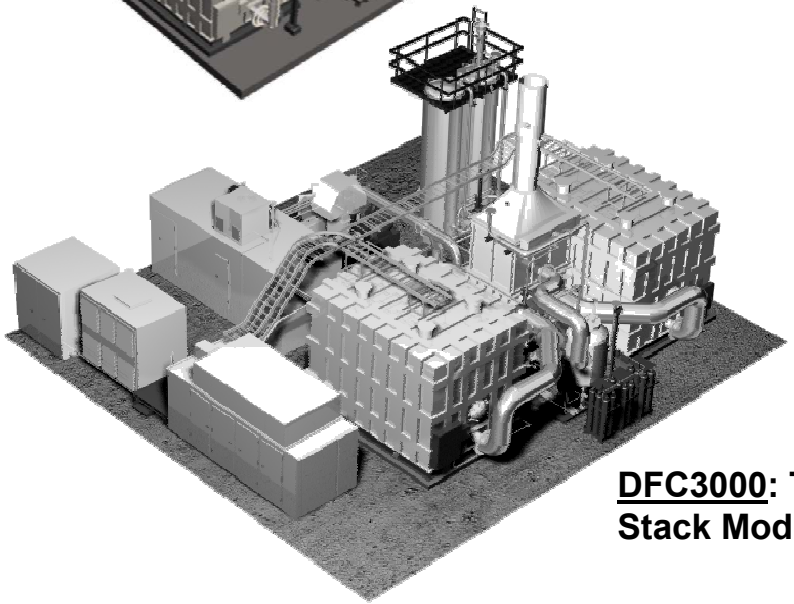
DFC300
Single Module Power Plant



DFC1500A
Four Module Power Plant



DFC1500B
One 4-Stack Module



DFC3000: Two 4 Stack Modules

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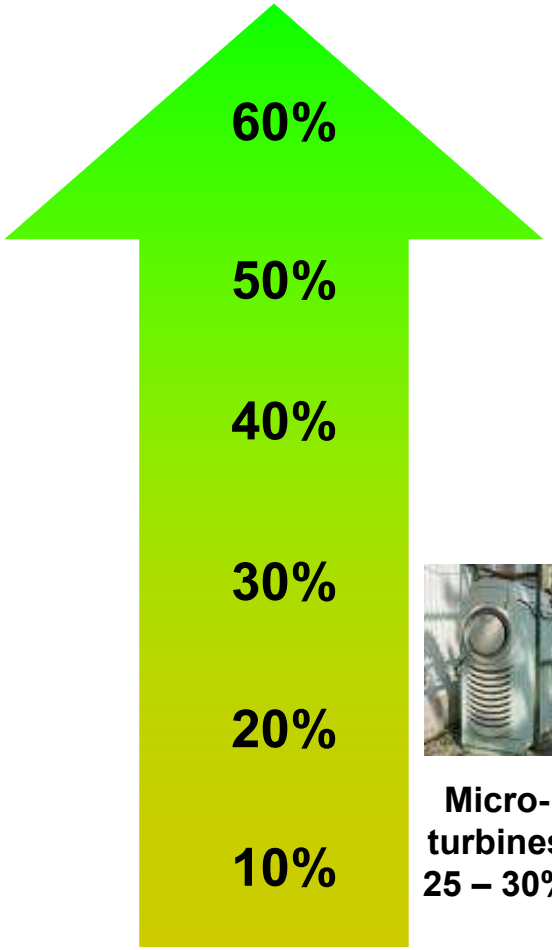
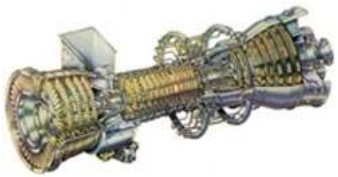
High Electrical Efficiency

DFC power plants offer the highest efficiency of available distributed generation technologies



Micro-turbines
25 – 30%



Small Gas Turbines
25 –35%

Natural Gas Engines
30 – 42%

Direct FuelCell (DFC)
47%

DFC-H_2
DFC-ERG
DFC/Turbine
58 – 65%

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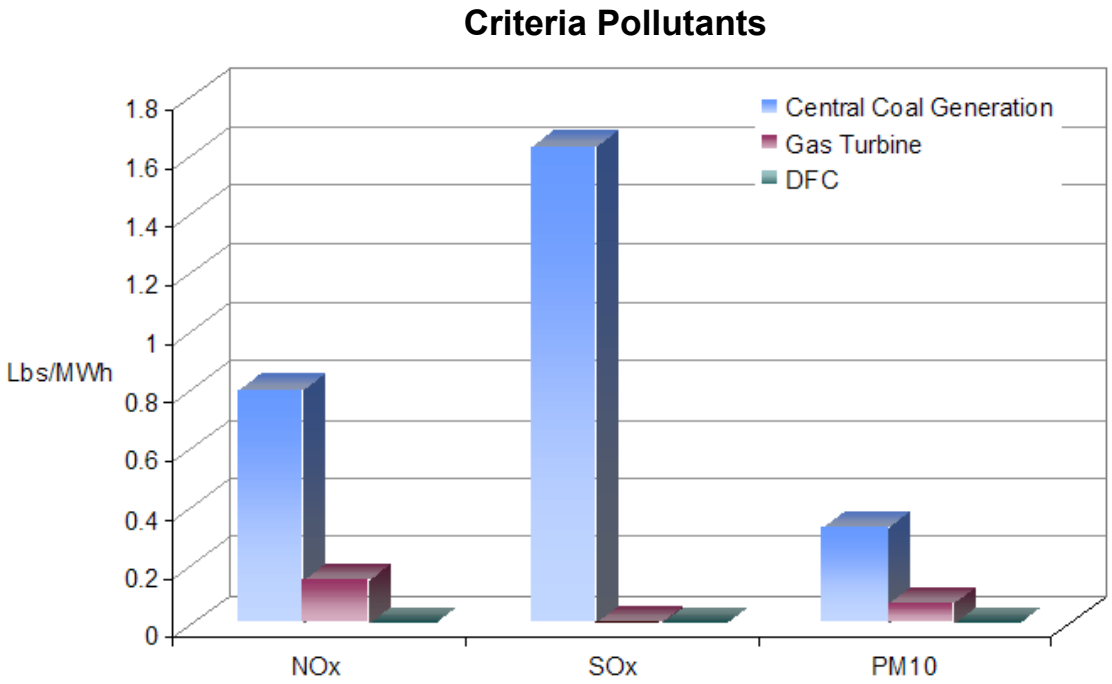
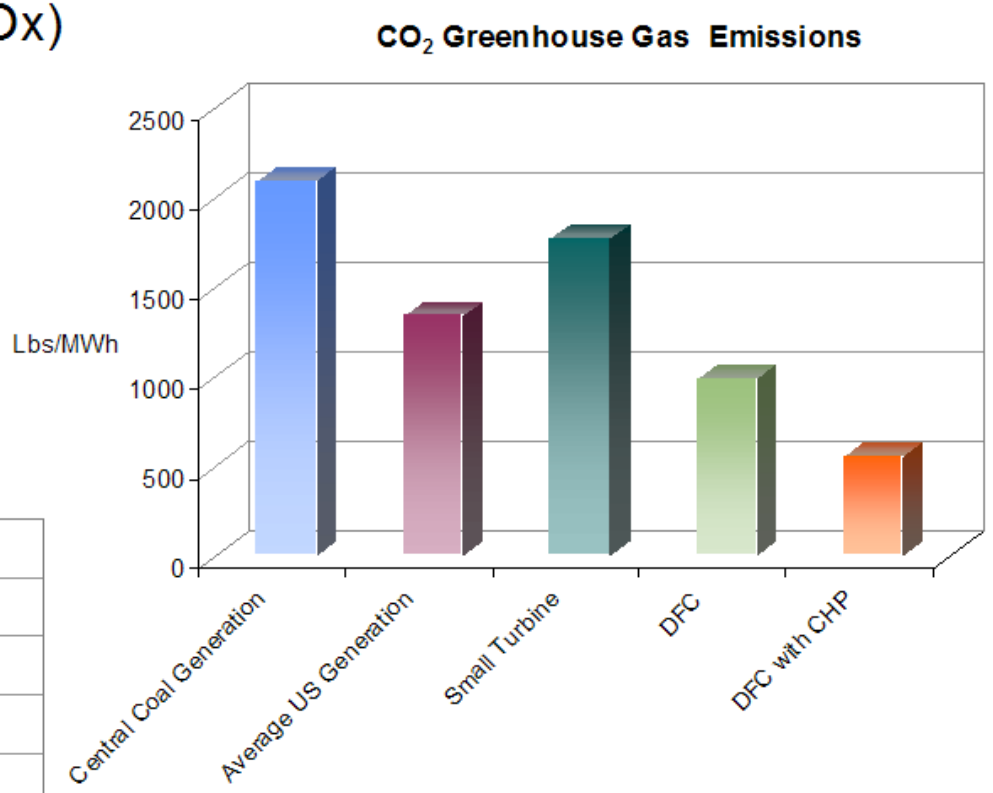
DFC Benefits: Environmental

- Emits virtually zero pollutants (NOx, SOx)
- Significantly reduced CO_2
- Quiet operation suitable for almost any location





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FCE History on Renewable Gas

Project Name	Date In Service	Total Output
King County, WA	06/2004	1 MW
Kirin Beer (Japan)	09/2003	250 kW
Fukoka (Japan)	01/2004	250 kW
LA County - Palmdale	08/2003	250 kW
Santa Barbara	09/2003	500 kW
Tancheon (Korea)	04/2006	250 kW
Super Eco Town (Japan)	06/2006	250 kW
Sierra Nevada Brewery	05/2005	1 MW
KEEP (Japan)	01/2006	250 kW
Tulare	10/2007	900 kW
Dublin-San Ramon	03/2008	600 kW
Rialto	10/2007	900 kW
Riverside	08/2008	1 MW
Turlock	10/2008	1.2 MW
Moreno Valley	10/2008	750 kW
Gills Onions	10/2008	600 kW
Livermore	Construction	600 kW
Point Loma	Construction	300 kW
San Diego	Construction	1.2 MW
UC San Diego	Construction	2.4 MW

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DFC1500 1 MW Plant at King County, Seattle

Municipal Wastewater Treatment Plant

First Site with On-Line Fuel Switching

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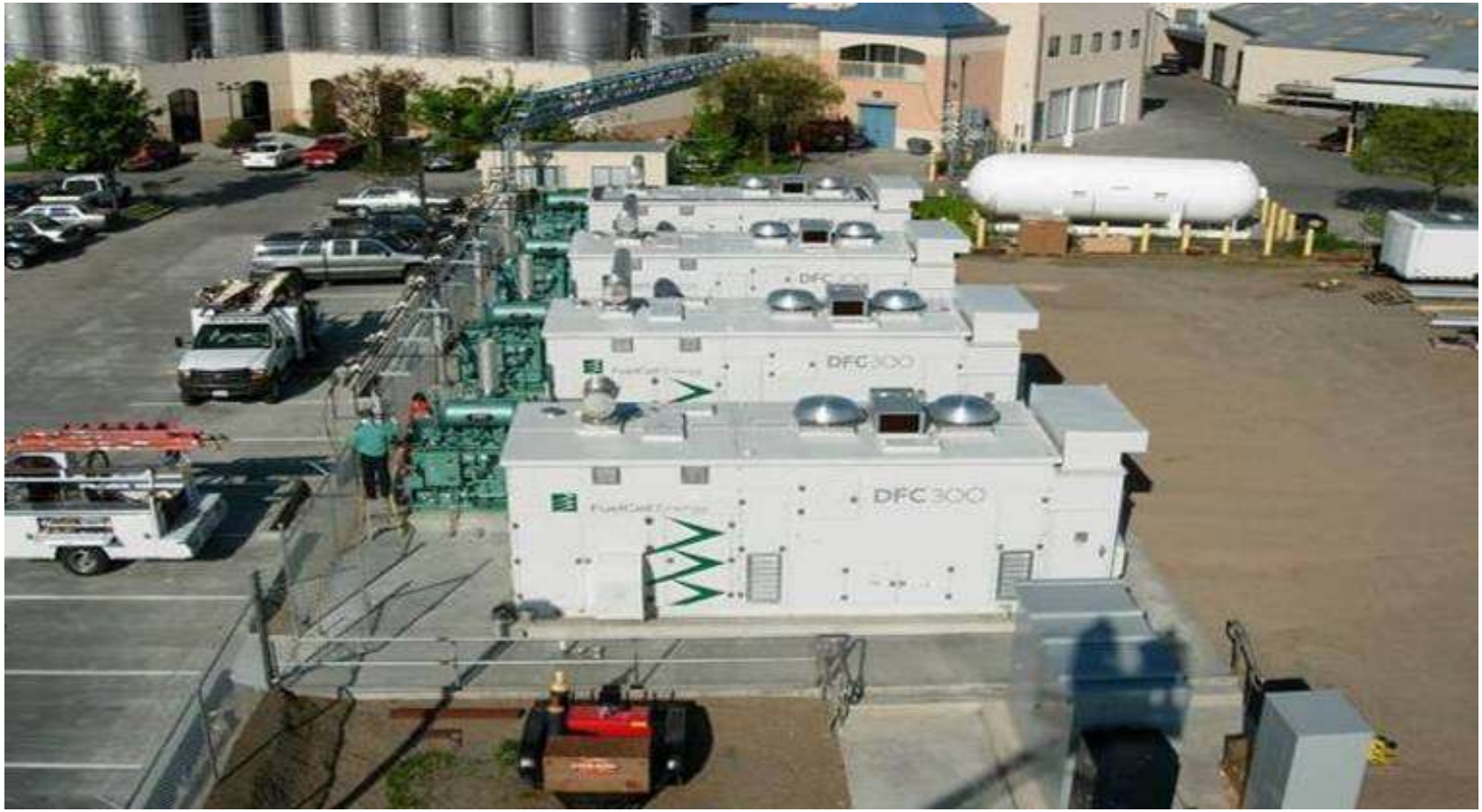
4 DFC300 Plants, Sierra Nevada Brewery, California



Brewery waste converted to ADG = 1 MW + Steam

First Site with Automated Fuel Blending

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Kyoto Eco-Energy Project (KEEP)

- **Fuel is Digester Gas from Food Waste**
- **Part of Mini-Grid with wind turbine, PV, & gas engines connected in parallel to the local electrical grid**

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Current Biogas Fuel Cell Installation

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Current Biogas Fuel Cell Installation

City of Riverside – 1 MW Biogas Fuel Cell – Dedicated August, '08

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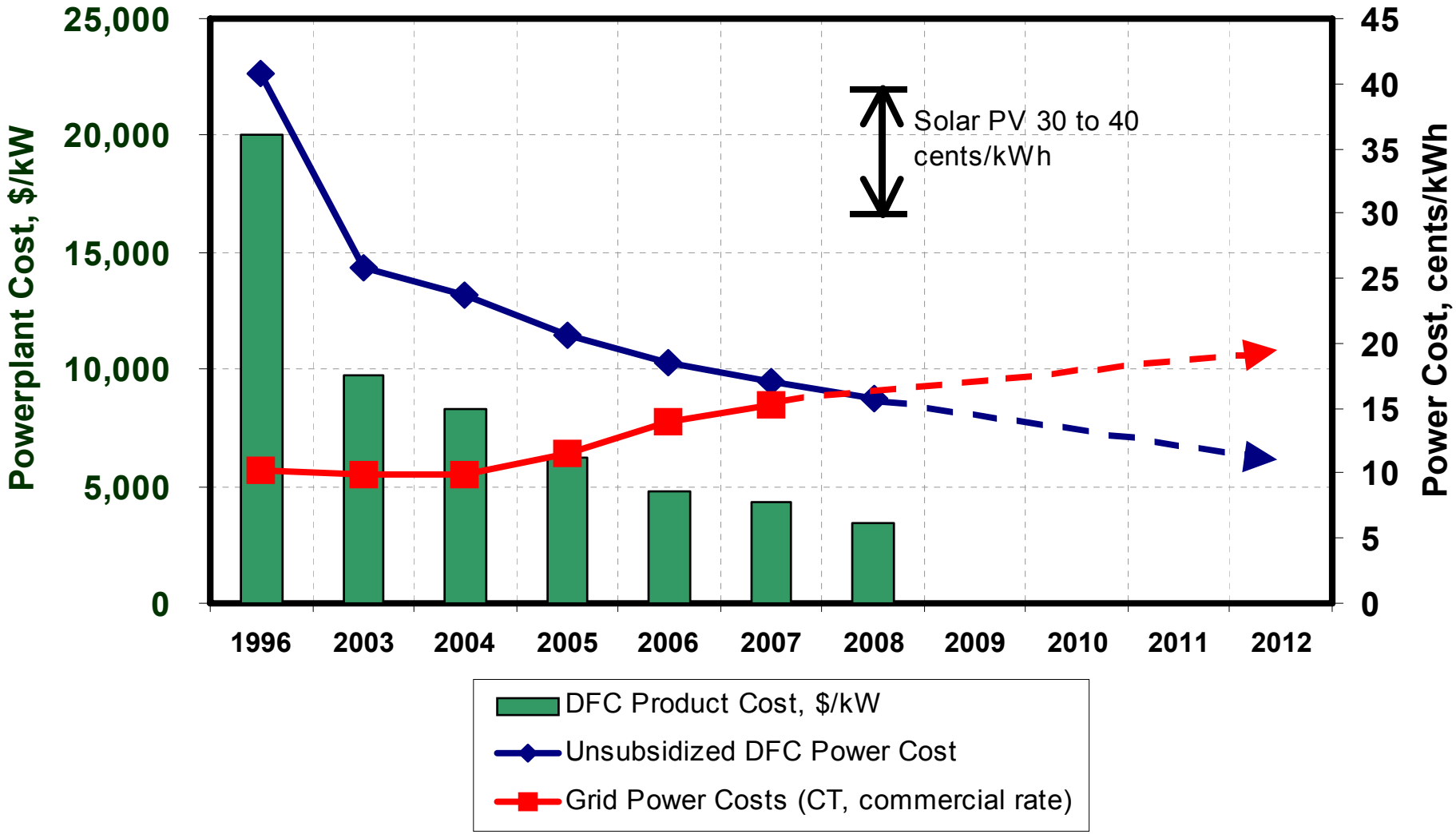
Cost Effectiveness

DFC power plant costs are declining while the cost of grid power increases



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DFC-H_2 Power Plant: Trigeneration System

DFC-H_2 POWER PLANT

kWs to electric load: 50%

Commercial/Industrial Building

Heat to buildings
thermal load: 15%

Hydrogen: 20%

H_2 – REFUELING STATION

Multiple Co-products
Improve Asset Utilization

Business Model?

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Co-production of H_2 and Electricity Using DFC

DFC Power Plant	Electrical Output [kW]	Hydrogen Produced [lbs/Day]	Fuel Cell Fleet Vehicles Serviced [approx.]*
DFC-300	250 kW	300	~300
DFC-1500	1000 kW	1,200	~1,200
DFC-3000	2000 kW	2,400	~2,400

* DOE-Air Products' Study

DFC-300MA

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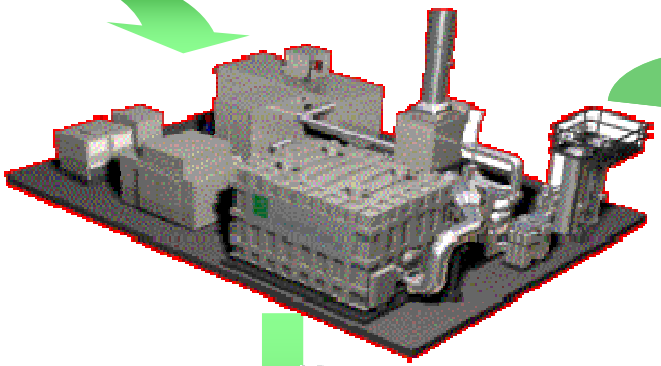
Double the Value of Renewable Fuels

65% Efficiency (H_2 + Electrical) before Waste Heat Recovery

DFC Fuel Cell Power Plant



Renewable Fuel Source

(Waste Water Treatment Anaerobic Digester Gas, Biodiesel, Waste-Glycerol)

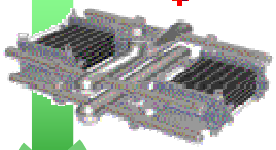
Power + Heat

Renewable Power Users

Buildings

Micro Grid

Industrial Use



H_2 Purification

Hydrogen

Low Pressure H_2 Users

NOx Reduction

Materials Handling Equipment

Peak Load Response

Industrial Use

Hydrogen Energy Station

Hydrogen Vehicles
(> 40% efficiency Well-to-Wheels Using Plug-in Hybrid Vehicle)

MO3183a

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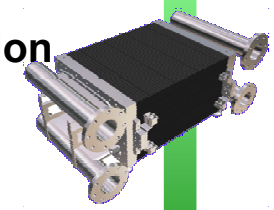
Hydrogen Energy Station
A Solution for Base Load and Peak Power

PEM/PAFC Fuel Cell

Peak Power
(Up to 1 MW)

Hydrogen

H_2 Purification



DFC Fuel Cell

Base Load Power
(1 MW)

MO3190
100308

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Demonstration of Hydrogen Energy Station Vision

- **DOE Program – Natural Gas Feed**
- **Potential Host Site Identified - OCSD**
  - Orange County Sanitation District, Fountain Valley, CA
  - Municipal Wastewater Treatment
  - Ability to Achieve Vision – Production of Renewable Hydrogen and Electricity
  - **Renewable Hydrogen Available for Export**

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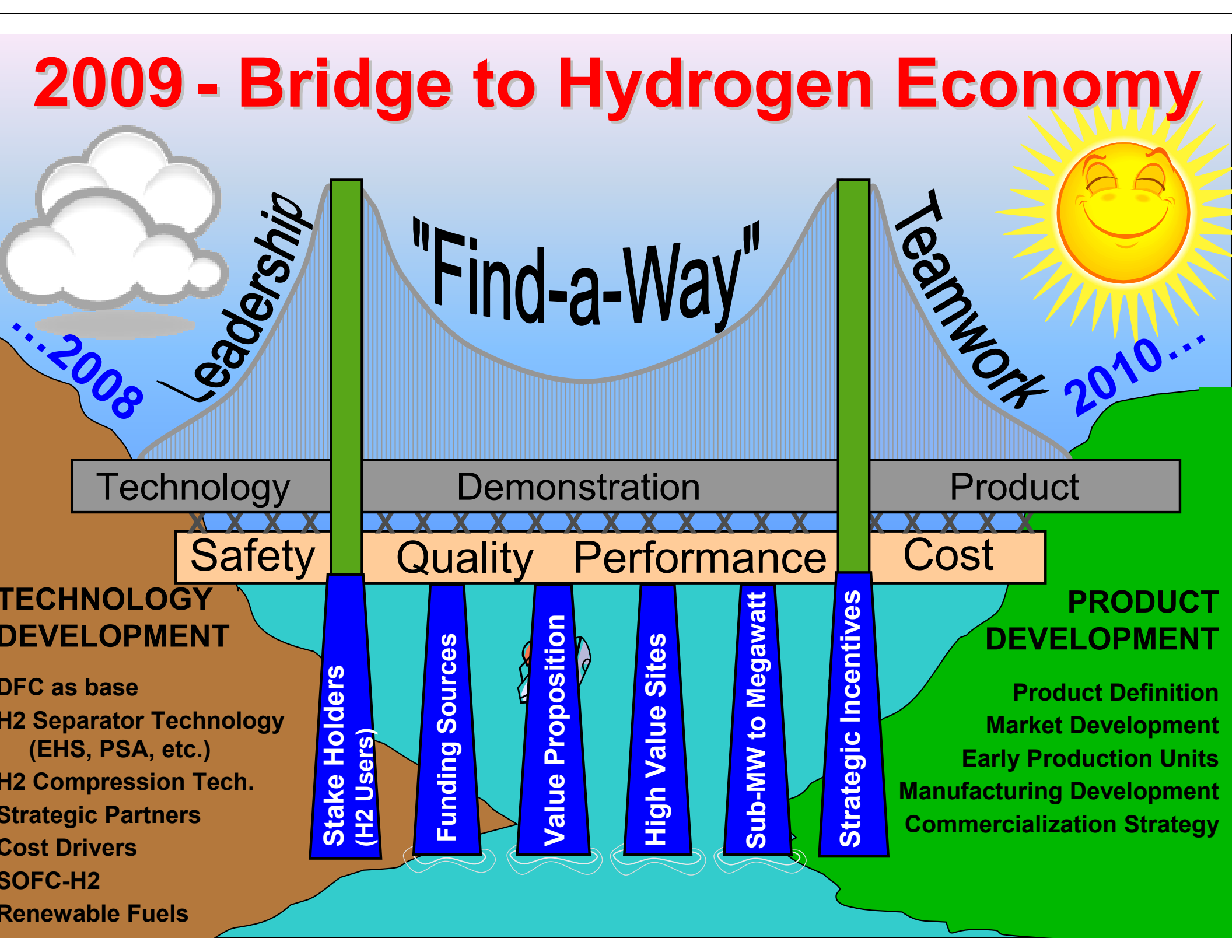
Strategic Input for the DOE Workshop

- Bridge to Hydrogen Economy and Needs
- Example of California Market Drivers
- Suggested Approach for Financial Incentives
- Advanced Technology Opportunities

2009 - Bridge to Hydrogen Economy



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California Market Drivers

- AB 32 passed – strict limits greenhouse gas emissions
- CARB 07 sets tough new standards for NO_X emissions
  - ALL FCE Products are CARB 07 certified on BOTH Natural Gas AND Biogas
- $80 million + annual incentive program for clean energy generation projects (Self-Gen Incentive Program)
- $2500/kW for power plants running on natural gas
- **$4500/kW for power plants running on biofuels**
- 40% of FCE's total installed capacity
- Hydrogen Highway initiative
  - Hydrogen fueling infrastructure
  - $200 million/yr new initiative CARB + CEC

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Suggested Approach for Financial Incentives

Incentive Category	Suggested Approach
1. Co-products	
- Power	$/kW and/or ¢/kWh
- Hydrogen	$/kg-$H_2$ capacity and/or $/kg-$H_2$ produced
- Thermal	CHP vs. CH_2P
2. Fuel Type	
- Natural gas	Baseline incentive
- Renewable fuels	Additional incentive (eg. ethanol, biodiesel)
- Waste derived fuels	Highest incentive (eg. Digester gas, landfill gas, glycerol, industrial waste gas)
3. Emission Reduction	
- Criteria pollutants (NO_X, SO_X, etc.)	$/ton (avoided)
- GHG	$/ton (avoided)

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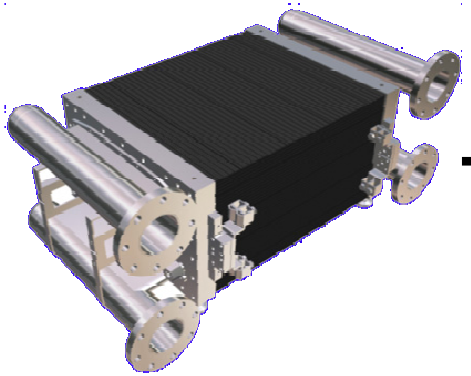
R&D Opportunities

DFC Power Plant
(Electricity + Hydrogen)



Electrochemical
Hydrogen Separator
(EHS)

Electrochemical
Hydrogen Compressor
(EHC)

H_2

FC Car

FC Bus

MO3145

Advanced Technology Opportunities for Hydrogen Refueling Applications

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Summary: Co-production of Hydrogen

- Improved Asset Utilization: Co-production of hydrogen and electricity improves the operating economics - facilitates hydrogen infrastructure for military as well as civilian applications
- Renewable Hydrogen: DFC power plants operating on digester gas at over a dozen sites – a source of low-cost hydrogen
- Flexible Co-production: Maximizes overall value proposition
- Status: A renewable H_2 co-production demonstration using an Air Products PSA hydrogen separation system is planned
- Advanced Separation System: Electrochemical hydrogen separator promises up to 50% reduction in operating cost

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